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Ascent Aerodynamic Pressure Distributions on WB001

B. Vu, J. Ruf, F. Canabal
CFD Branch

J. Brunty
System Load Branch

To support the reusable launch vehicle concept study, the aerodynamic data and surface pressure for WB001 were predicted using three CFD codes at several flow conditions during the ascent phase. The results have been compared between code to code and code to aerodynamic database as well as available experimental data. A set of particular solutions have been selected and recommended for use in preliminary conceptual designs. These CFD results have also been provided to the structure group for wing loading analyses.

Ascent Aerodynamics Analysis of WB001 Configuration

B.T. Vu
J.H. Ruf
F. Canabal
J. Brunty

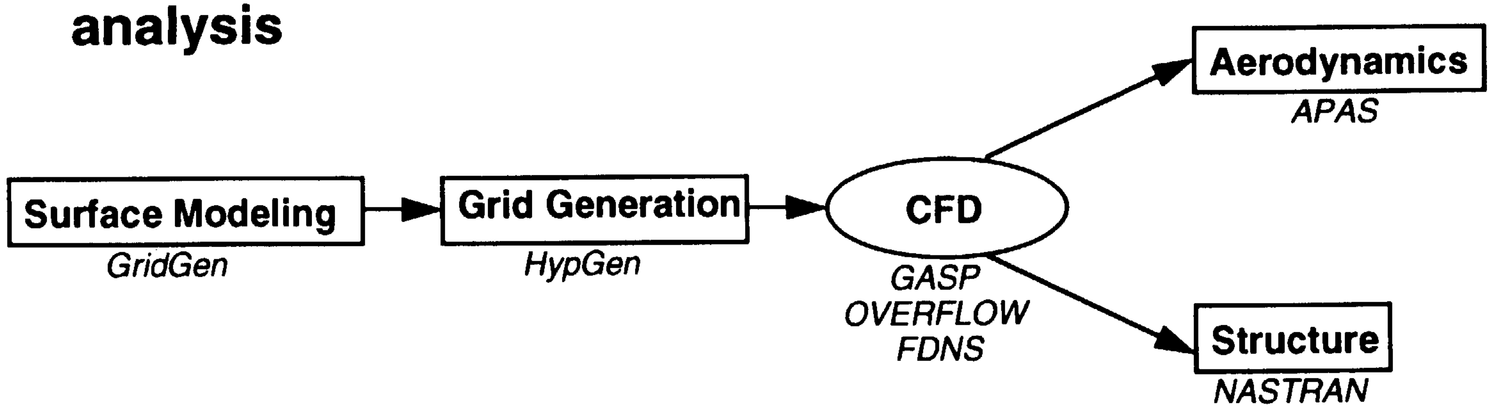
OUTLINE

- Objectives
- Codes employed
- Cases considered
- Results and discussions
- Structural analyses
- Conclusions

RLV Concept Study Review

OBJECTIVES

- Predict the flow field environment during ascent
- Compute the aerodynamic coefficients
- Provide three-dimensional surface pressure for structure analysis



CODES EMPLOYED

- **OVERFLOW**
  - capable of solving overset grids
  - used at ARC and JSC for orbiter analyses
- **GASP**
  - finite-volume, density-based
  - used at LaRC and Wright Patterson for NASP vehicle design
- **FDNS**
  - finite-difference, pressure-based
  - used at MSFC for reacting flow analyses

CASES CONSIDERED

Transonic (M=1.1)	Supersonic (M=5.72)		
AOA 6°	AOA 0°	6°	8°
GASP inv./vis.		*GASP vis.*	
OVERFLOW inv/vis.	*OVER FLOW vis.*	*OVER FLOW vis.*	*OVER FLOW vis.*
FDNS vis.			

RESULTS & DISCUSSIONS

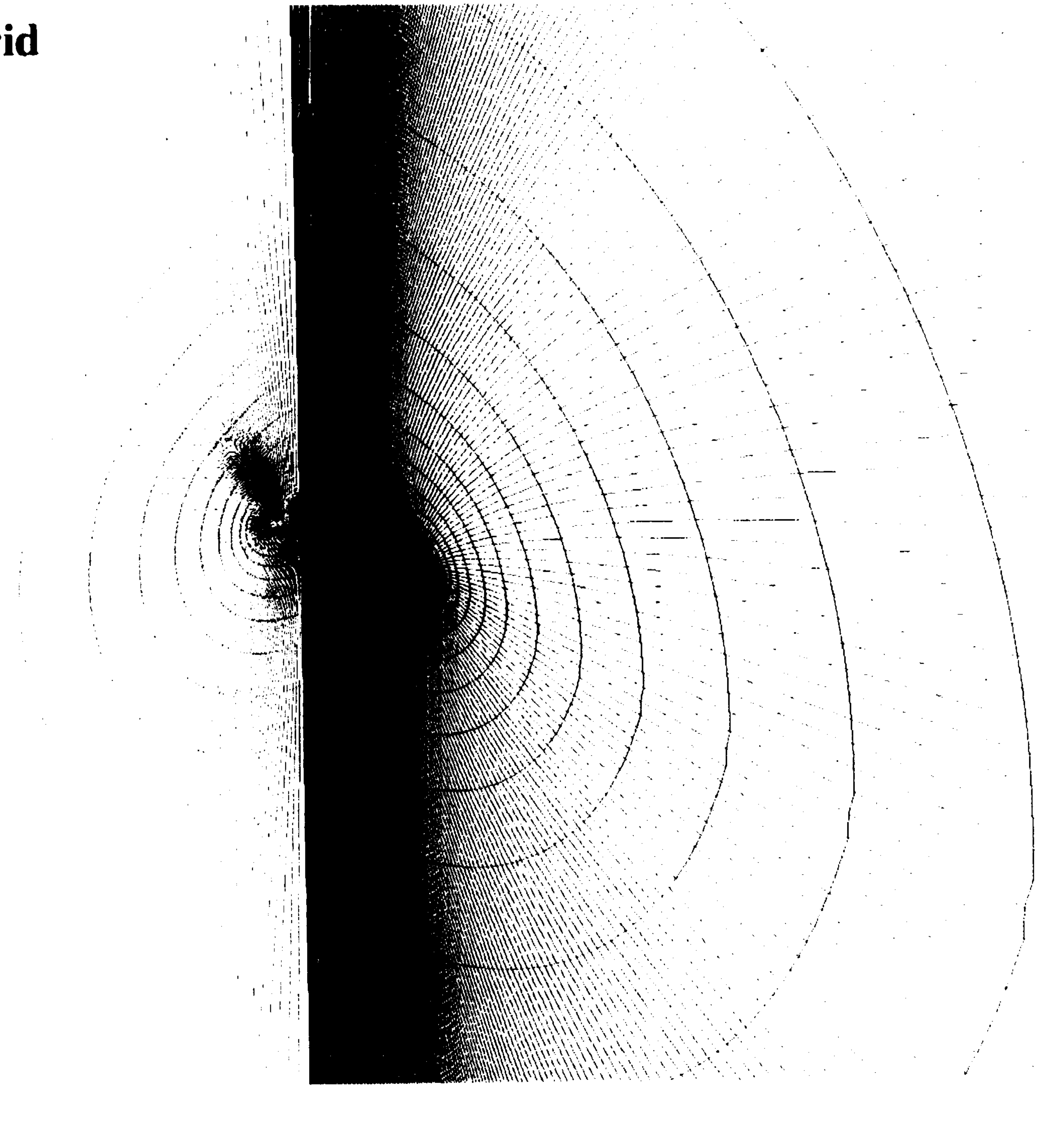
- Computational domain for both cases properly generated to capture physics associated flow conditions

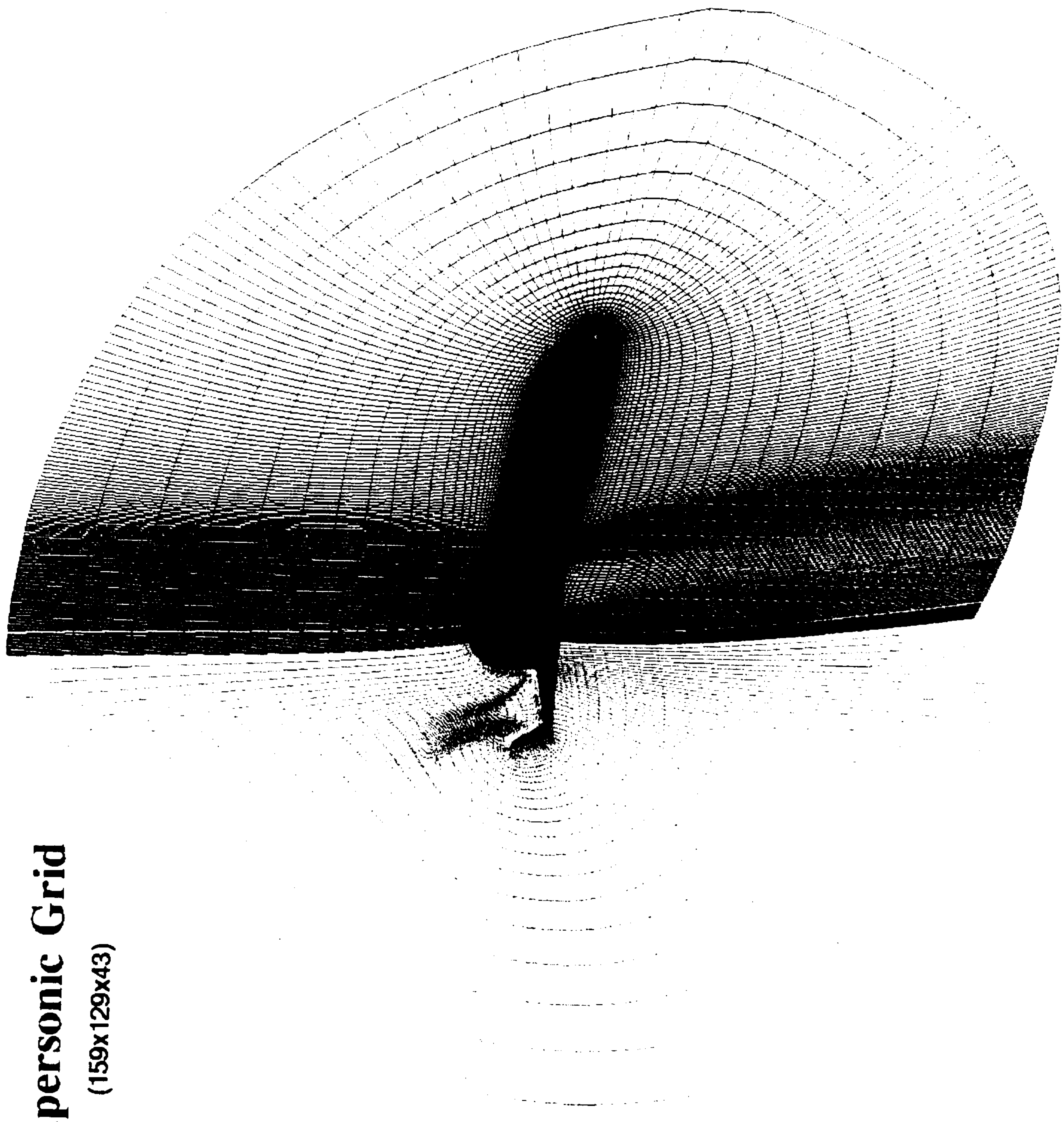
- Surface pressure and symmetry Mach contours
  - good agreement for surface pressure
  - good agreement centerline Mach contours

- Pressure coefficients for vehicle nose
  - predicted stagnation Cp agrees with isentropic theory
  - **M = 1.1 Cp=1.36 (CFD / GASP)**
  - **M = 1.1 Cp=1.34 (Theory)**

Transonic Grid

(159x129x65)





Supersonic Grid

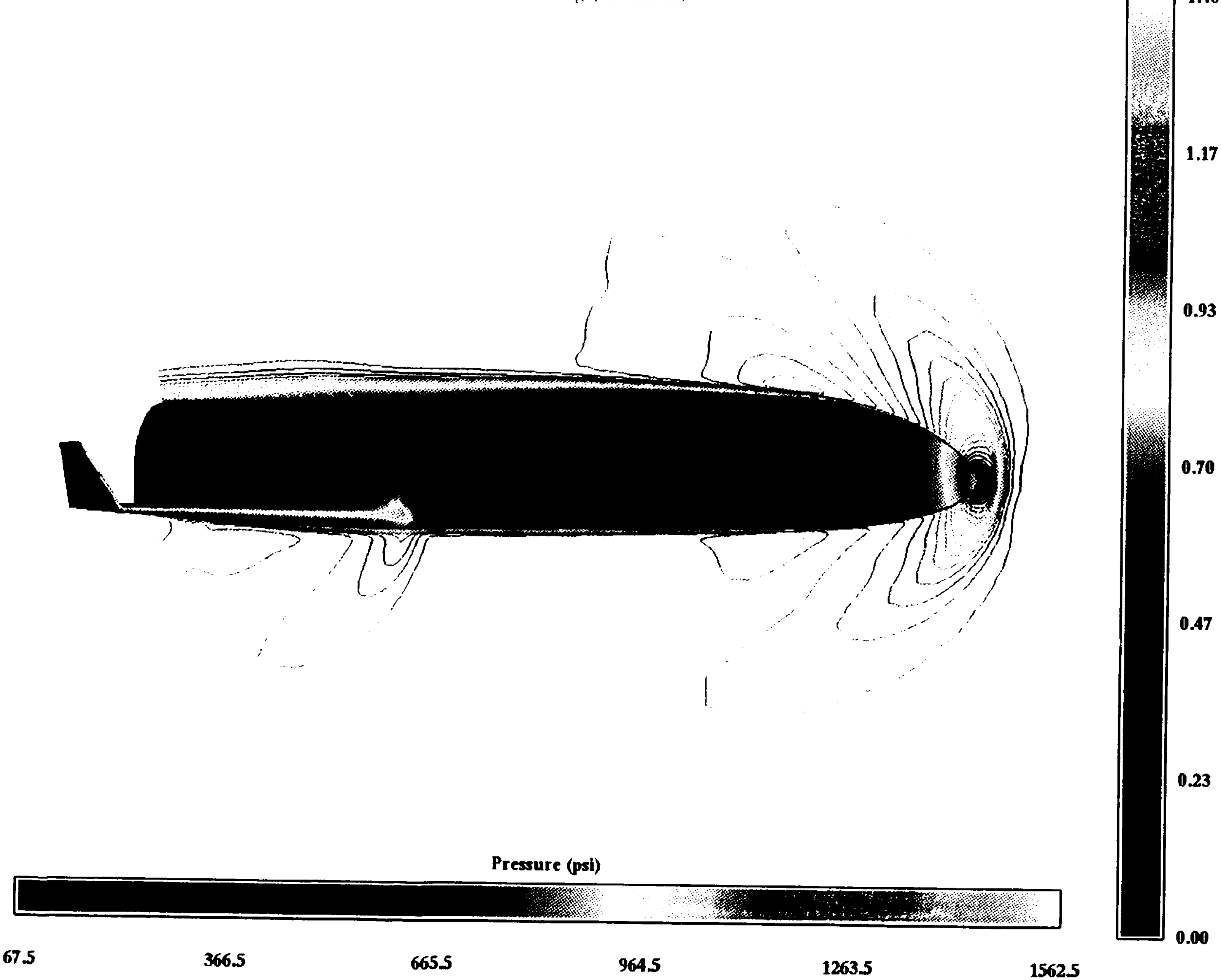
(159x129x43)

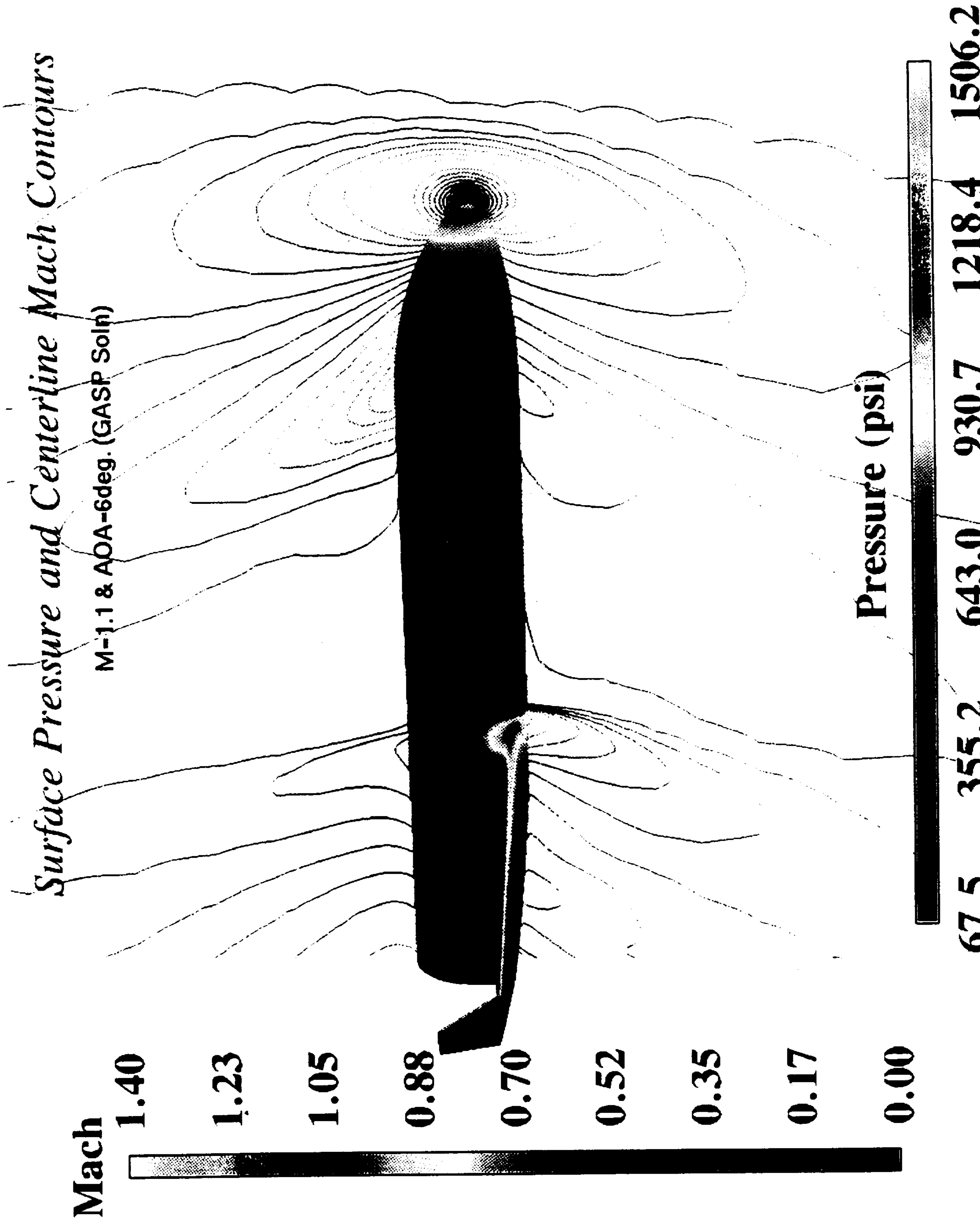
COMPARISONS

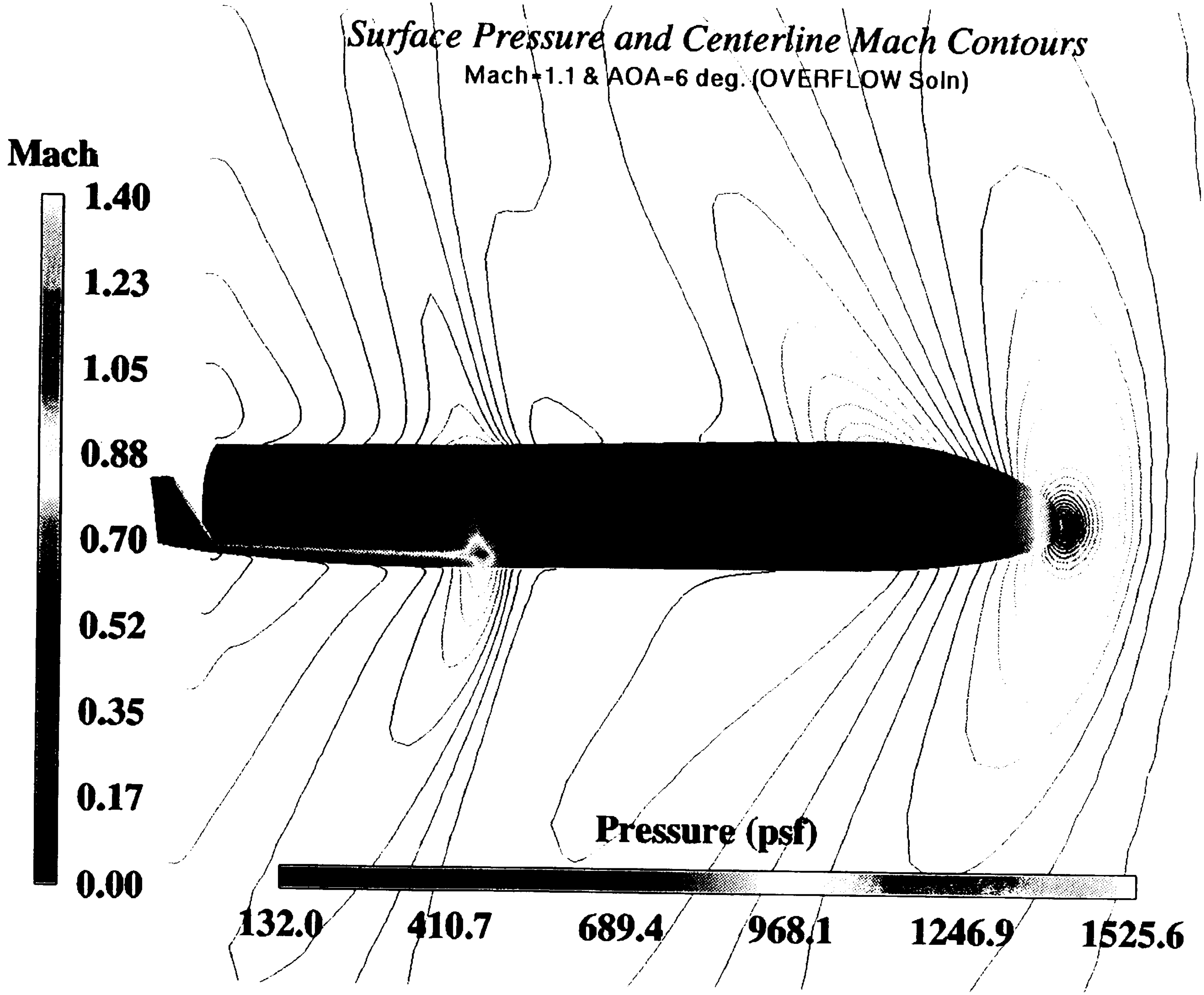
- **Code-to-code comparison**
  - good agreement for surface pressure and centerline Mach contours
- **3 aerodynamic coefficients are compared between codes and with APAS database**
  - excellent agreement in high supersonic case
  - good agreement in transonic case

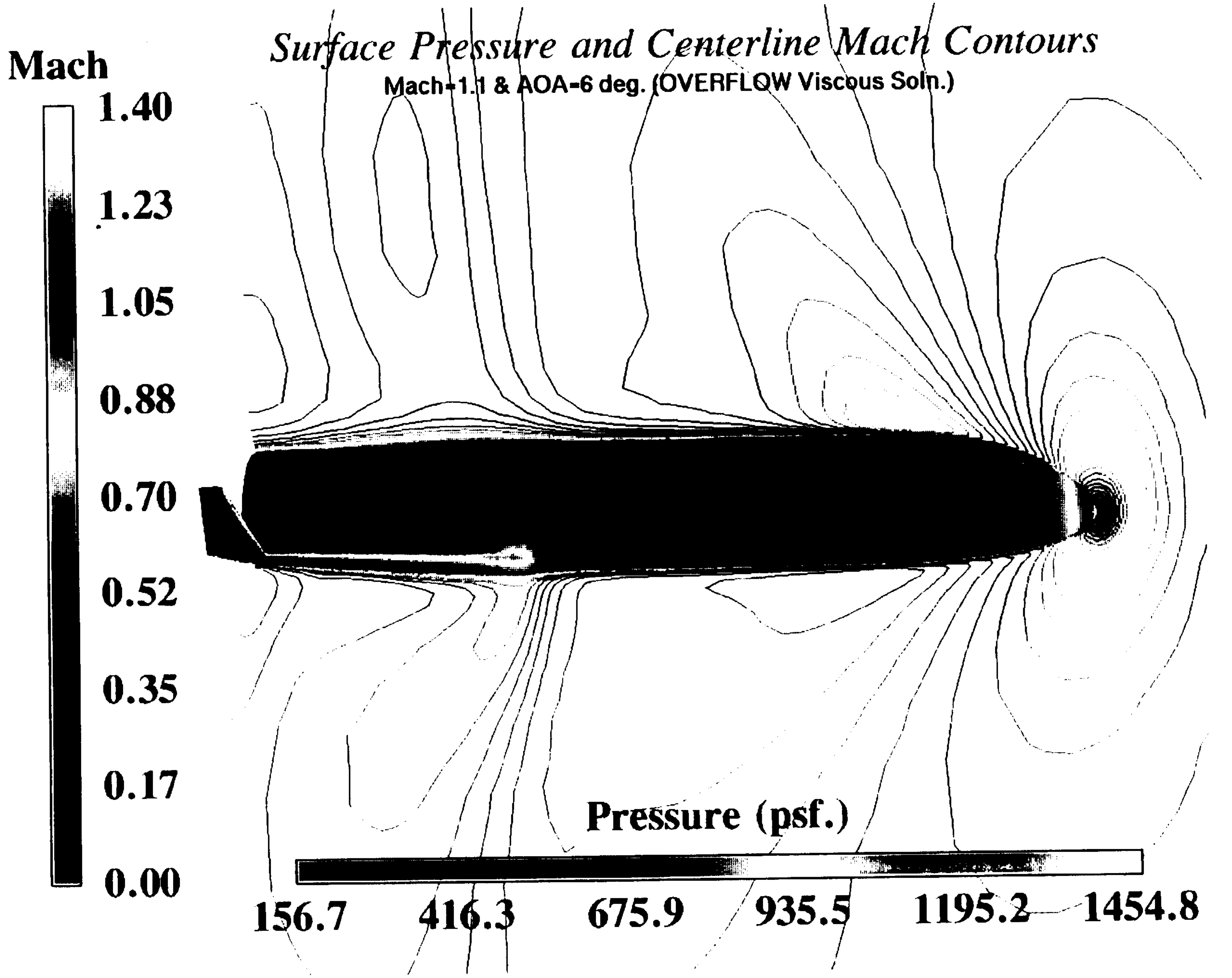
Surface Pressure and Centerline Mach Contours

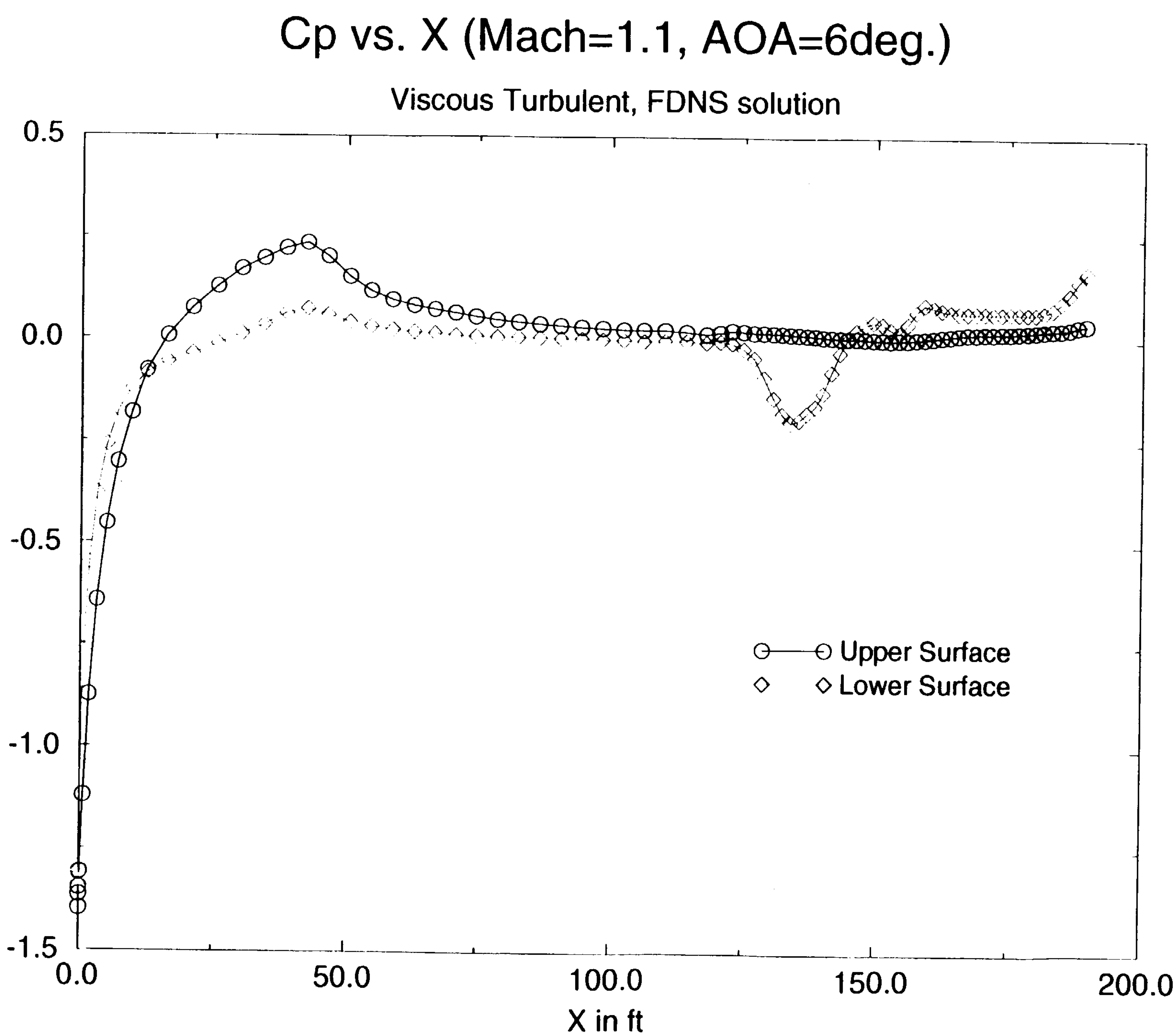
M 1.1 & AOA 6deg. (FDNS soln)

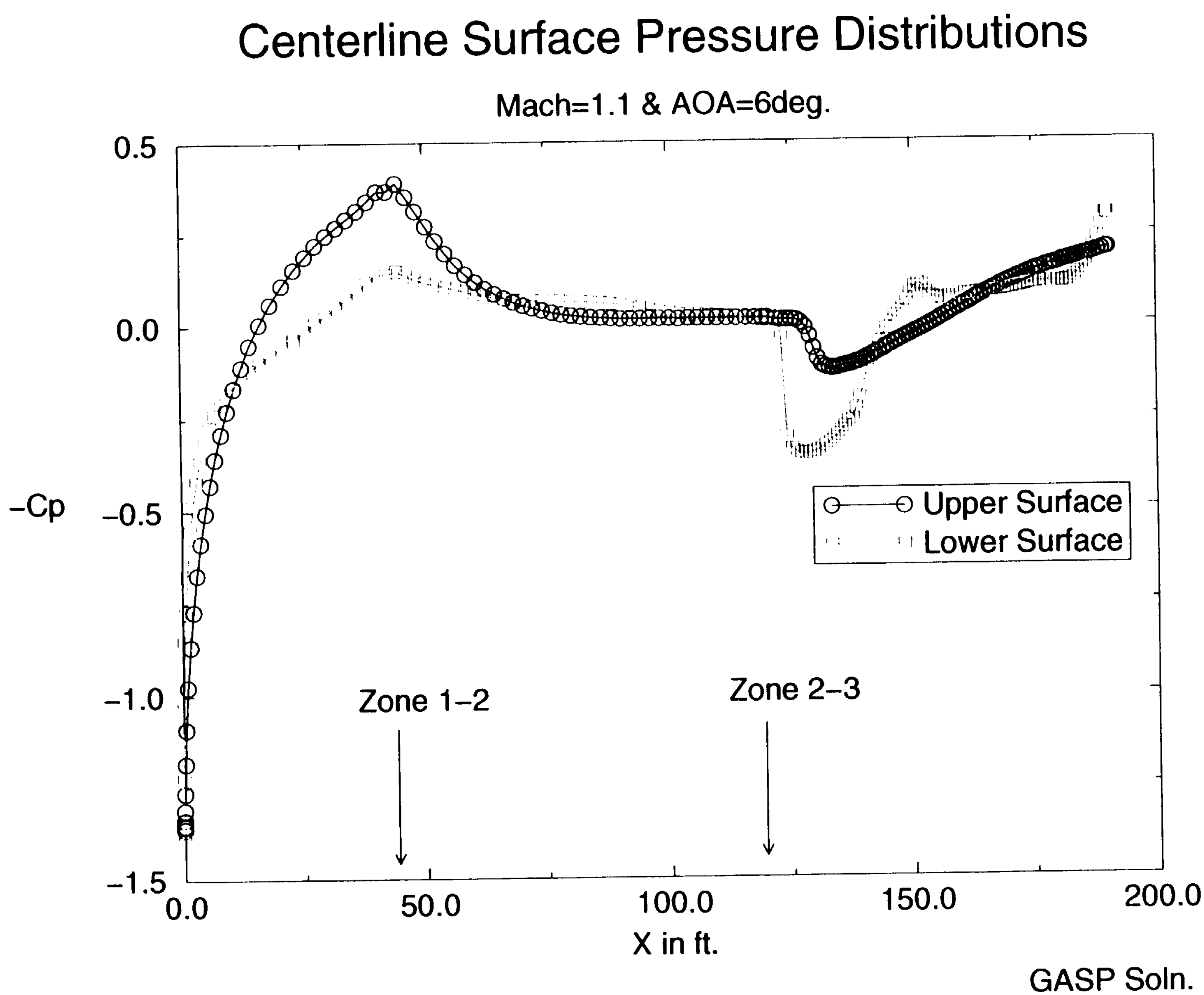


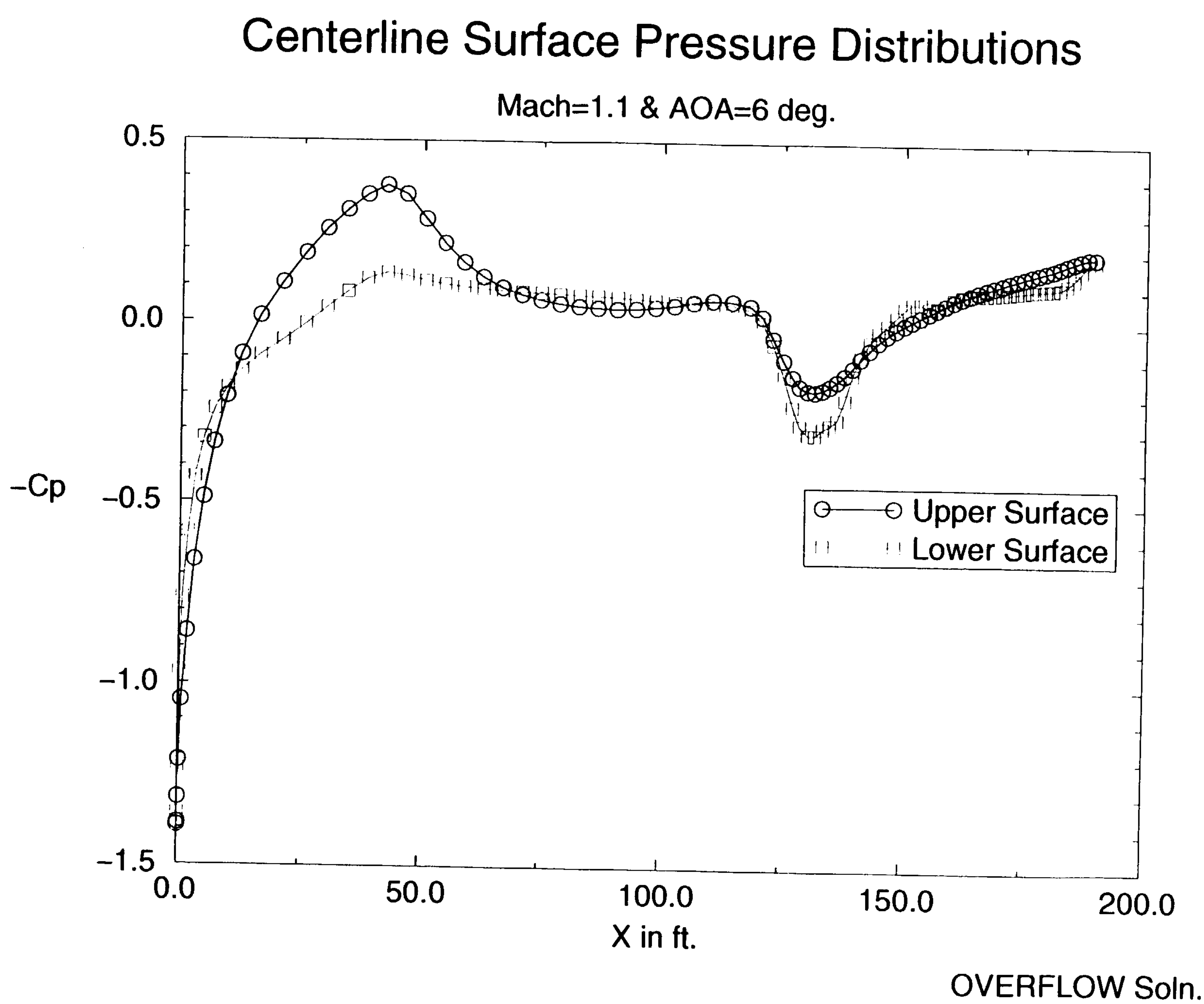

Surface Pressure and Centerline Mach Contours
M-1.1 & AOA-6deg. (GASP Soln)
Mach
1.40
1.23
1.05
0.88
0.70
0.52
0.35
0.17
0.00
Pressure (psi)
67.5
355.2
643.0
930.7
1218.4
1506.2


Surface Pressure and Centerline Mach Contours
Mach=1.1 & AOA=6 deg. (OVERFLOW Soln)
Mach
1.40
1.23
1.05
0.88
0.70
0.52
0.35
0.17
0.00
Pressure (psf)
132.0
410.7
689.4
968.1
1246.9
1525.6


Surface Pressure and Centerline Mach Contours
Mach=1.1 & AOA=6 deg. (OVERFLOW Viscous Soln.)
Mach
1.40
1.23
1.05
0.88
0.70
0.52
0.35
0.17
0.00
Pressure (psf.)
156.7
416.3
675.9
935.5
1195.2
1454.8

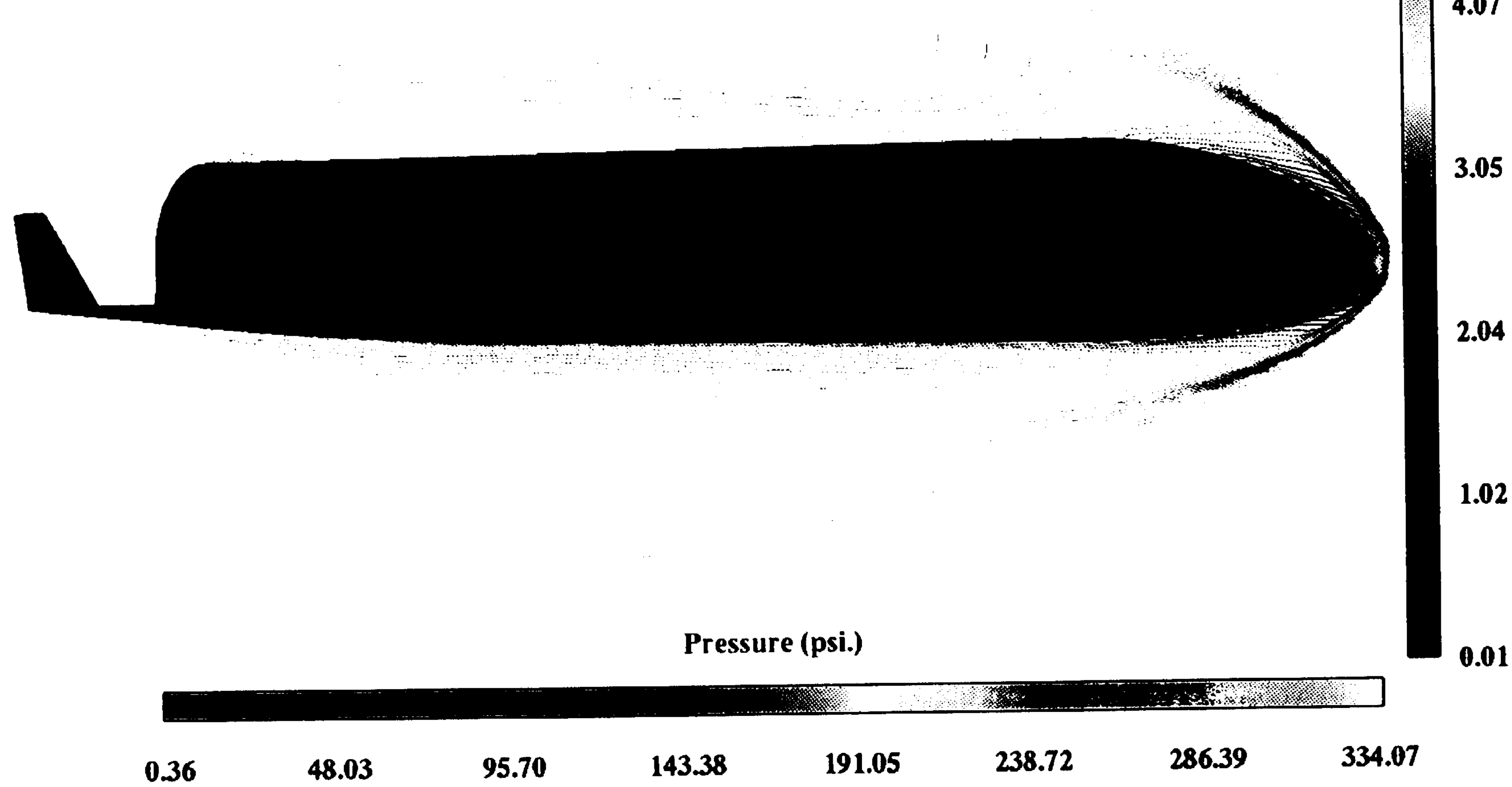

Cp vs. X (Mach=1.1, AOA=6deg.)
Viscous Turbulent, FDNS solution
0.5
0.0
-0.5
-1.0
-1.5
0.0
50.0
100.0
150.0
200.0
X in ft
Upper Surface
Lower Surface


Centerline Surface Pressure Distributions
Mach=1.1 & AOA=6deg.
-Cp
0.5
0.0
-0.5
-1.0
-1.5
0.0
50.0
100.0
150.0
200.0
X in ft.
Zone 1-2
Zone 2-3
Upper Surface
Lower Surface
GASP Soln.


Centerline Surface Pressure Distributions
Mach=1.1 & AOA=6 deg.
0.5
0.0
−0.5
−1.0
−1.5
−Cp
0.0
50.0
100.0
150.0
200.0
X in ft.
Upper Surface
Lower Surface
OVERFLOW Soln.

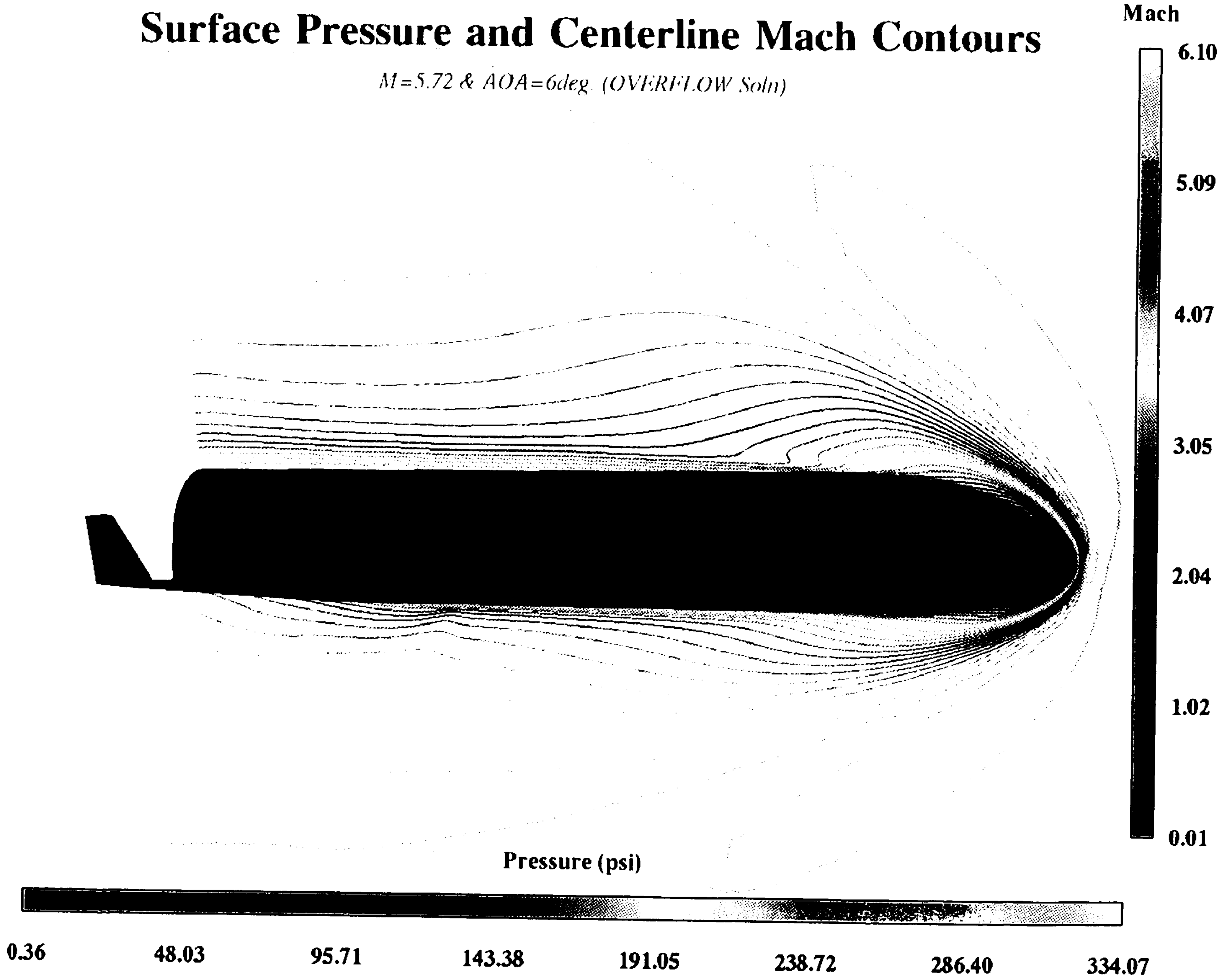
Surface Pressure and Centerline Mach Contours

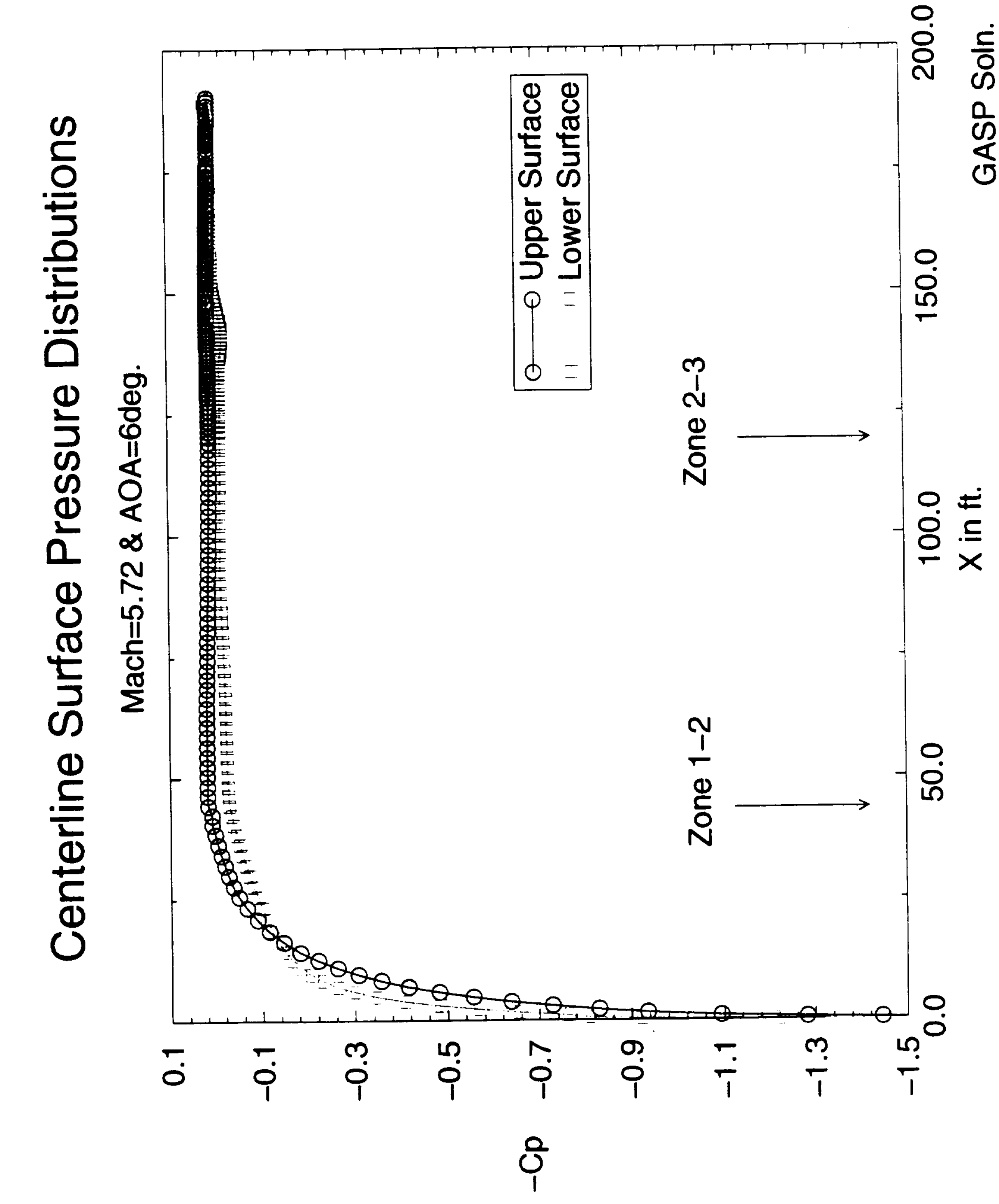
M=5.72 & AOA=6deg. (GASP Soln)



Surface Pressure and Centerline Mach Contours

M=5.72 & AOA=6deg. (OVERFLOW Soln)

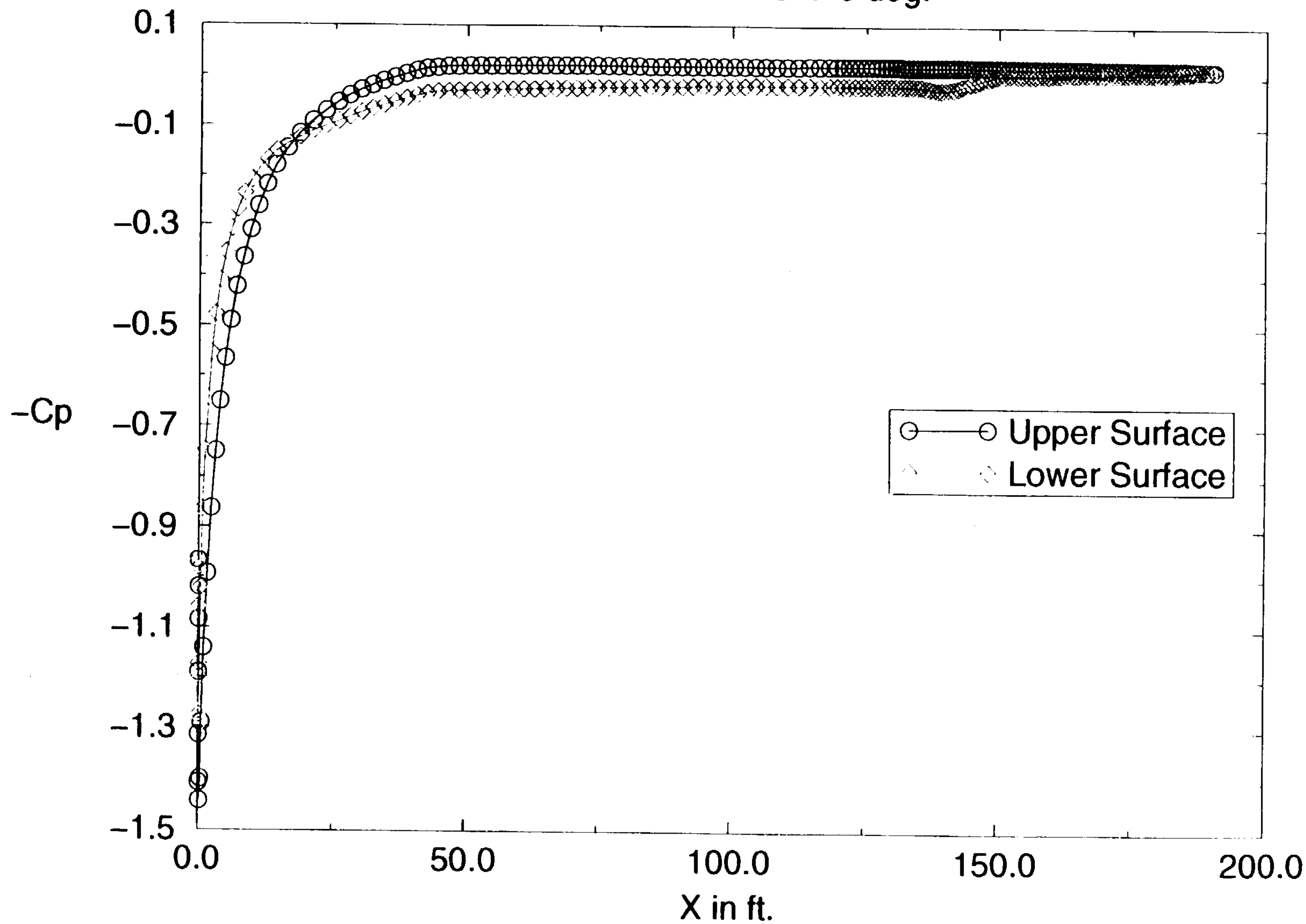




Centerline Surface Pressure Distributions
Mach=5.72 & AOA=6deg.
-Cp
0.1
-0.1
-0.3
-0.5
-0.7
-0.9
-1.1
-1.3
-1.5
0.0
50.0
100.0
150.0
200.0
X in ft.
GASP Soln.
Upper Surface
Lower Surface
Zone 1-2
Zone 2-3

Centerline Surface Pressure Distributions

Mach=5.72 & AOA=6 deg.



OVERFLOW Soln.

RLV Concept Study Review

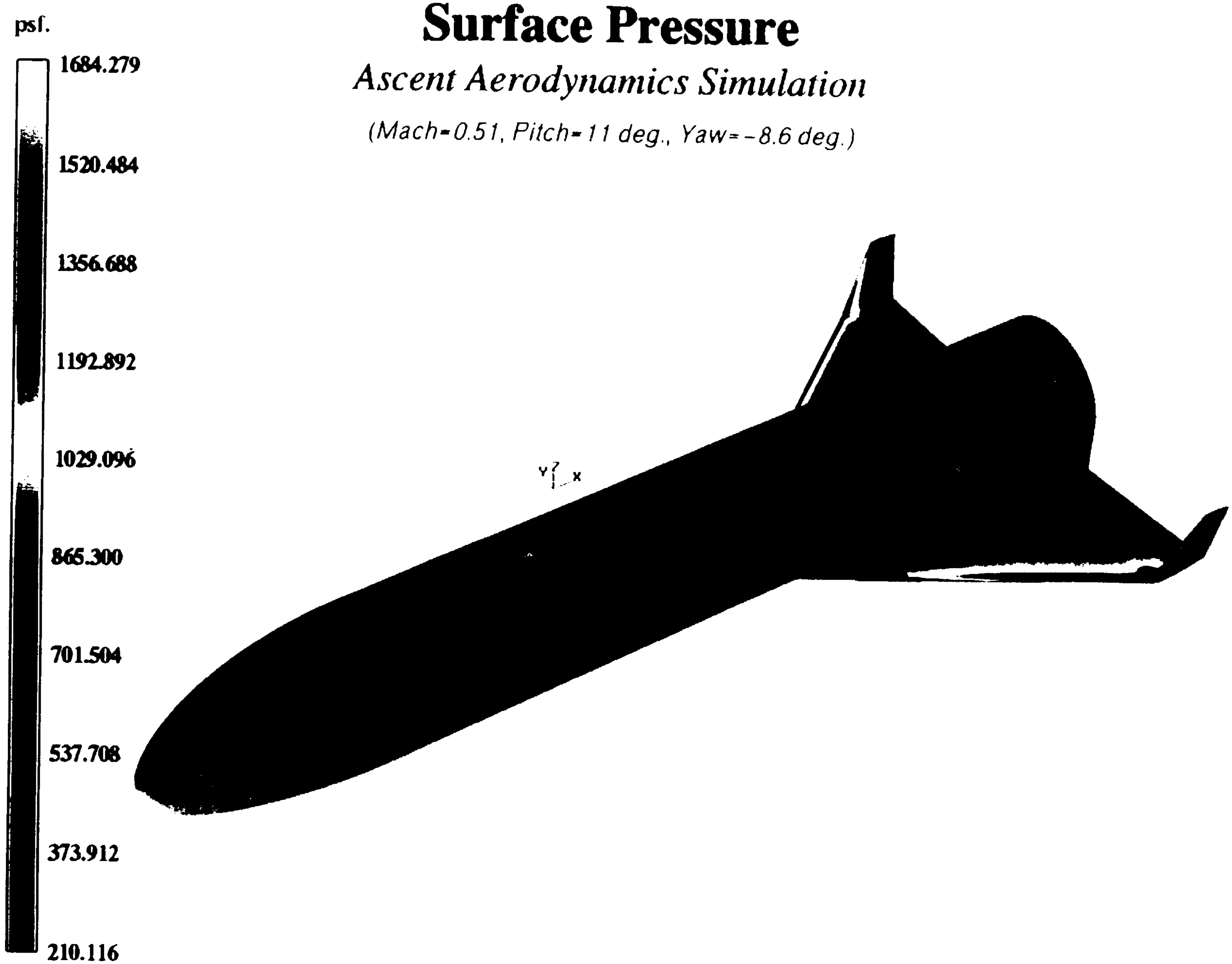
- **Predicted aerodynamic coefficients**

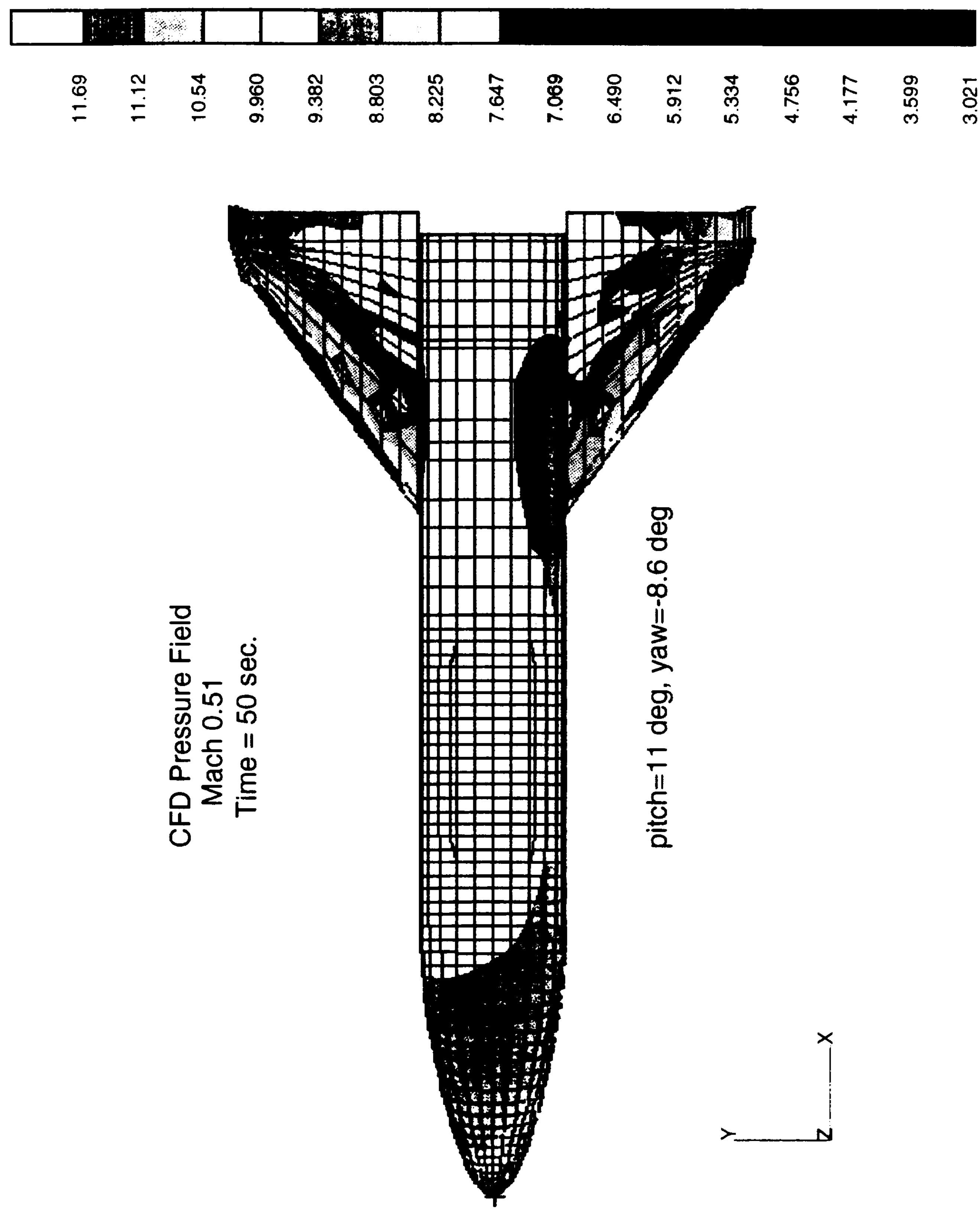
	APAS	OVERFLOW	GASP (inv.)	GASP(vis.)
***Transonic* (M=1.10 & α=6 °)**				
C_N	0.34	0.31	0.32	0.31
C_A	0.12	0.23	0.20	0.22
C_M	-0.049	-0.035	-0.041	-0.04
***Supersonic* (M=5.72 & α=6 °)**				
C_N	0.07	0.0672	N/A	0.0651
C_A	0.07	0.0714	N/A	0.0735
C_M	-0.002	-0.0028	N/A	-0.0033

Surface Pressure

Ascent Aerodynamics Simulation

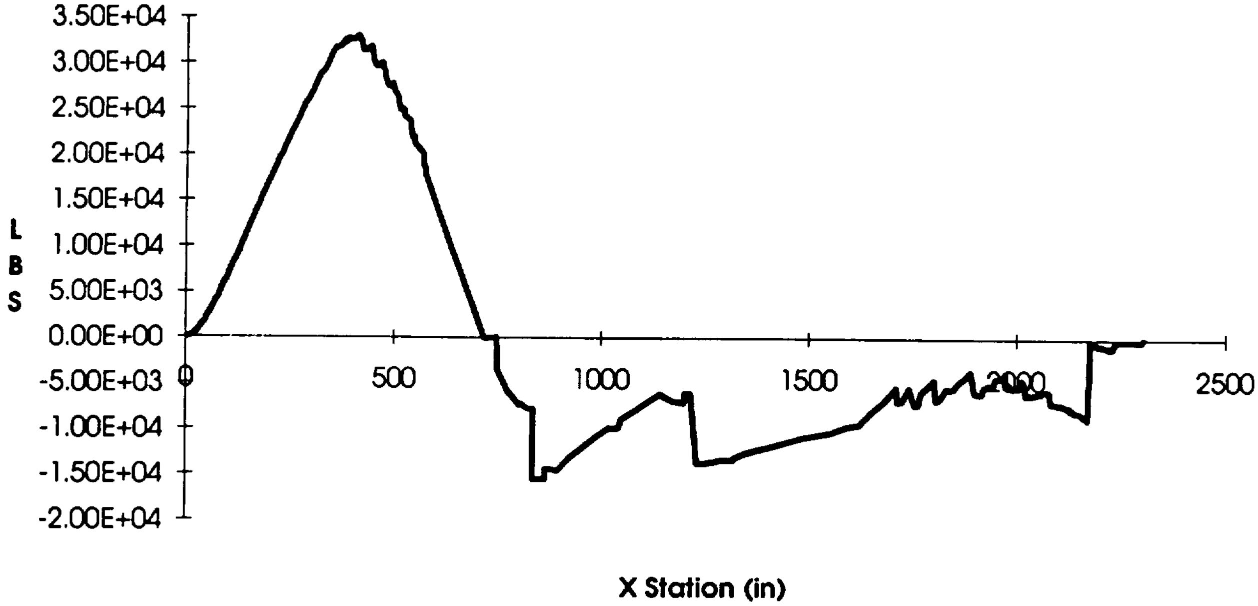
(Mach=0.51, Pitch=11 deg., Yaw=-8.6 deg.)



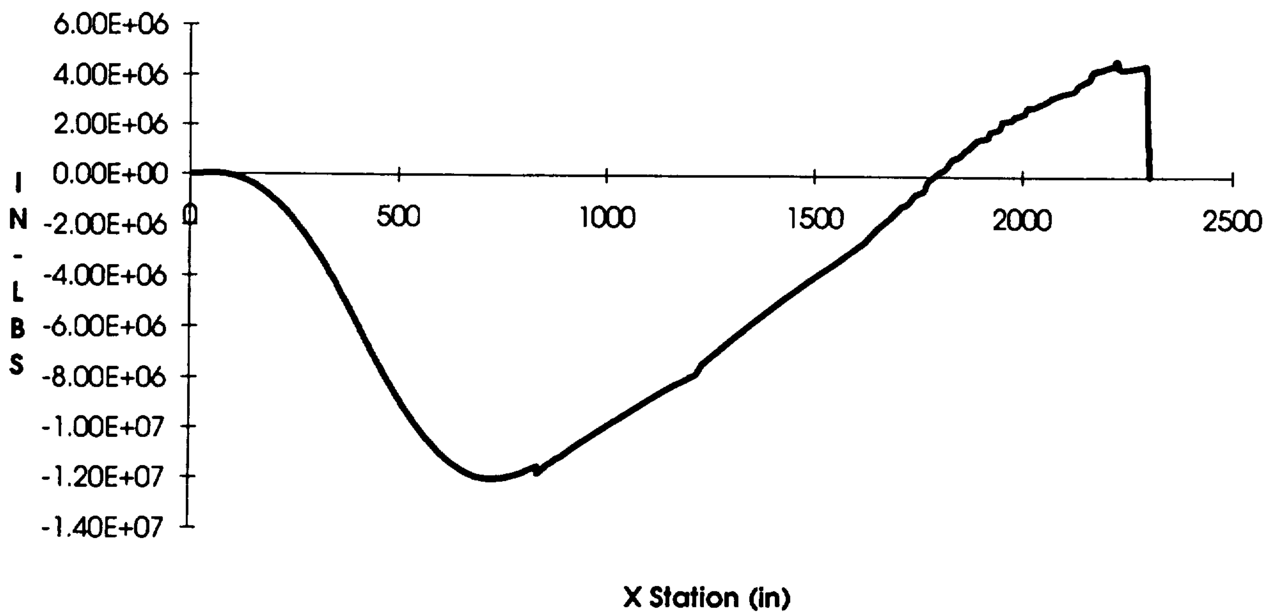


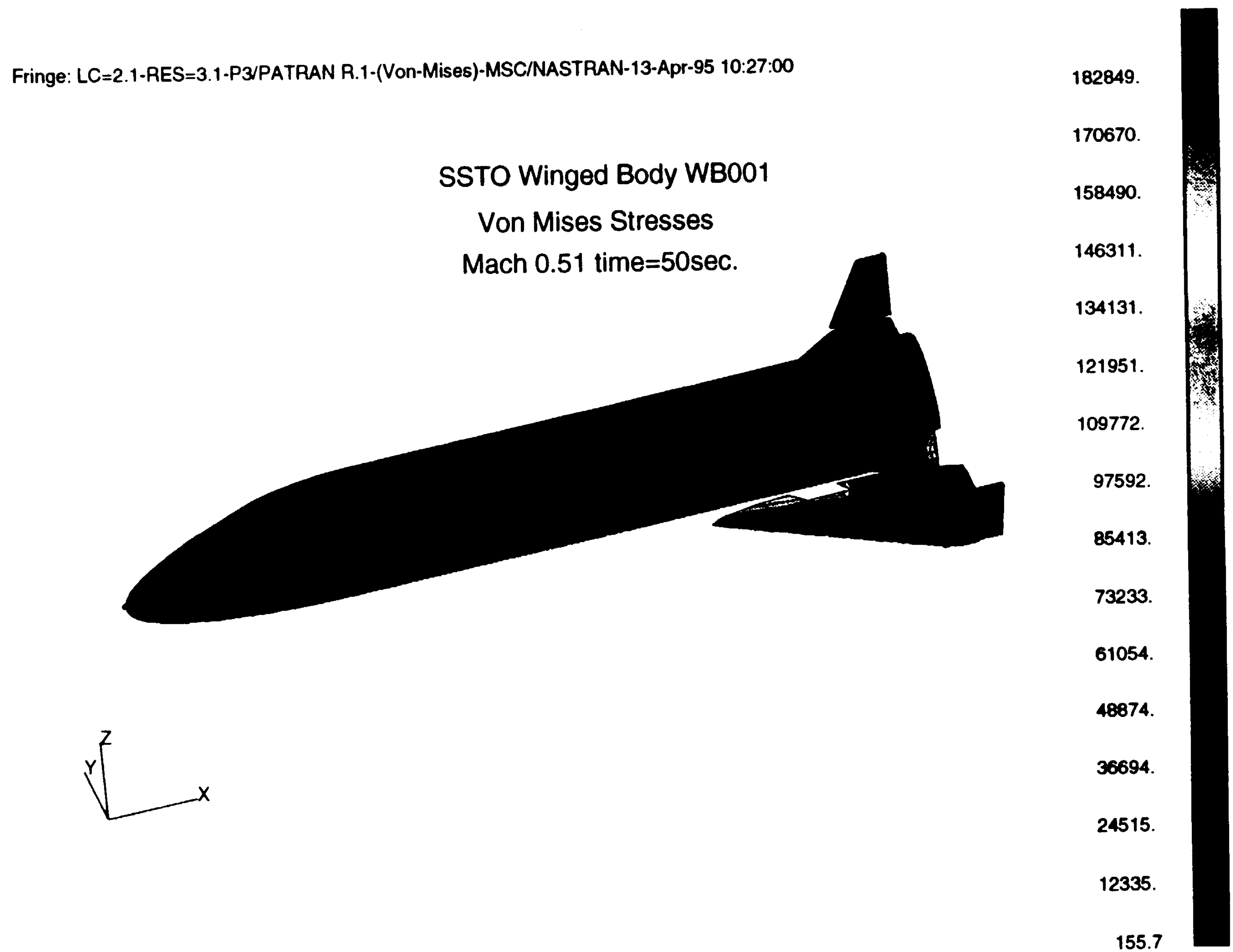
11.69
11.12
10.54
9.960
9.382
8.803
8.225
7.647
7.069
6.490
5.912
5.334
4.756
4.177
3.599
3.021
CFD Pressure Field
Mach 0.51
Time = 50 sec.
pitch=11 deg, yaw=-8.6 deg
Y
Z
X

Mach 0.51 T=50 sec. with Trim - Y Shear



Mach 0.51 T=50 sec. with Trim - RZ Moment




Fringe: LC=2.1-RES=3.1-P3/PATRAN R.1-(Von-Mises)-MSC/NASTRAN-13-Apr-95 10:27:00
SSTO Winged Body WB001
Von Mises Stresses
Mach 0.51 time=50sec.
182849.
170670.
158490.
146311.
134131.
121951.
109772.
97592.
85413.
73233.
61054.
48874.
36694.
24515.
12335.
155.7
Z
Y
X

CONCLUSIONS

- Predicted aerodynamic data and surface pressure for WB001 using 3 three codes at several flow conditions
- 3D finite element model and CFD pressure distribution provides the visual representation regarding structural deformations, load paths and stress patterns
- Base flow interactions (plume expansions, base recirculations, etc.) could affect the overall solutions; therefore must be considered in future work